Global mapping and characterization of Titan's dune fields with Cassini: correlation between RADAR and VIMS observations

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Introduction: Titan, the largest moon of Saturn, is the only one to possess a dense atmosphere and a great variety of morphological structures on its surface. Thanks to the Cassini-Huygens mission and its micro-waves and infrared imaging capabilities (RADAR in SAR mode, VIMS and ISS) large dunes fields were discovered in the equatorial region. These features represent clues for the understanding of the climatic history on Titan [1, 2]. Gathering the spectral ability of the VIMS instrument and the locations and morphology of dunes available with the spatial resolution of RADAR/SAR, we are now able to map the geographic distribution of Titan's dunes, to precisely quantify their coverage and to provide some constraints on the nature of the material that compose them; with the final aim to figure out the mystery of the processes that are implied on this satellite and to understand its complex climatology. In this paper, and according to previous works [3-7], we will present updated global maps in infrared and microwaves wavelength and updated estimates of dune coverage. We will also discuss the degree of correlation between the dunes imaged by the RADAR/SAR and some spectral units appearing in VIMS observations and discuss briefly the implication for dune material and compositional properties.

Dune coverage from RADAR/SAR observations: From October 2004 to June 2011 (Titan flybys TA-T77), the RADAR/SAR from best to coarser resolution imaged 52% of the surface of Titan (see fig. 1). The highest resolution of RADAR/SAR swaths offers the best detection of dunes fields. We find that dunes cover 11.2% of the SAR images of highest resolution (350m/pixel), which cover in total 40% of Titan's surface. Some dunes are also revealed at lower resolution (700m/pixel) accounting for 0.8% of the whole imaged surface. Putting all together, it finally corresponds to dune coverage of 9.3% of the area imaged by RADAR/SAR. This confirms that dunes are one of the most dominant feature on the Titan's surface (equivalent to 2/3 of the Europe area).

The identification and delineation of the dunes at the global scale confirm the previous studies of the particular distribution of this pattern essentially between 30°N-30°S (as proposed by [1] from TA-T55, see fig. 1 b)) with some isolated dunes at 50°N. The figure 1 b. shows in particular that, at the equator, although the RADAR/SAR has a lower coverage on average, dunes cover 60% of the RADAR swaths.

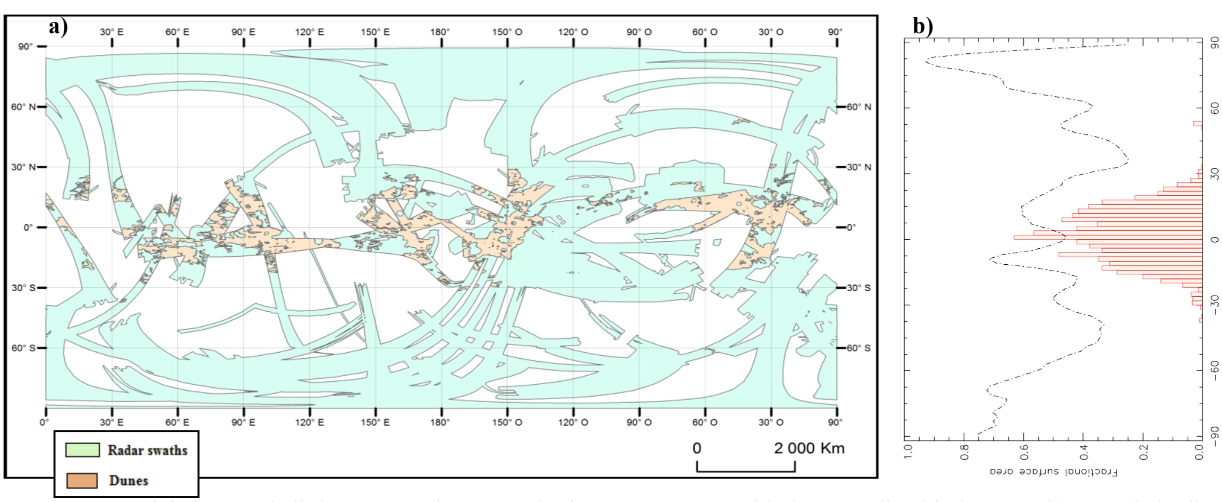

Figure 1: a) Global map of all the RADAR/SAR swaths from TA to T77, with dunes outlined in brown – b) Dune latitudinal distribution: The surface area covered by the dunes is normalized by the surface imaged by the RADAR/SAR TA-T77 (latitude bin=2°). The dashed line corresponds to the fractional surface area of surface imaged.

Correlation RADAR/VIMS and discussion: It has been suggested that global maps VIMS in composite color of band ratio (1.59/1.27µm, 2.03/1.27µm, 1.27/1.08µm) enhances spectral heterogeneity between terrains with two particular units: 1) Dark blue units which are suspected to be enrich in fine grain water ice [7, 8] and a dark brown unit which would be strongly correlated to the dunes imaged by the RADAR/SAR [5, 6]. In our up-to-date map, we outlined the "blue" and "brown" units from the map of [9] (see fig 2. a)). We compared the latitude distribution of the VIMS "brown" unit with the latitudinal diagram distribution given previously (see fig. 2 b)) and fig. 1 b)). We can conclude that they seem to be highly similar, at least in term of latitudinal extend.

Moreover, by overlapping all the sets of data (RADAR/SAR and VIMS) available so far, we observe an excellent geographic matching between the dunes imaged by the RADAR/SAR and the VIMS "brown" unit. Indeed, 77% of the dunes are found to be present in this unit.

With another statistic analysis, we also find that 70% of the area covered by the SAR swaths overlapping the "brown" unit, is covered by dunes. Our calculations consolidate the main hypothesis of correlation between the VIMS "brown" unit and the dunes imaged by the RADAR/SAR and demonstrate the high level of homogeneity of the dunes material, at the global scale. This is fully consistent with the uniformity of dune reflectivity and emissivity given by the RADAR [10, 11]. However, 1.5% of dunes are present in the VIMS "blue" unit while 20% of the SAR swaths belonging to this unit are covered by the dunes. The precise nature and origin of these bluish dunes are still unclear. They have been interpreted as enriched in water ice or dunes fields, which might present a lack of sediments in the inter-dune areas [4, 12].

According this analysis, we can with reasonably good confidence, extrapolate the total extent of dune fields of Titan to the total area of the VIMS "brown" unit, which extends the dune system to 18.5% of the whole surface of Titan (more than 15 million km^2, almost two times the total area of the USA). Considering the possible composition of Titan's "sand", dunes therefore represent the largest hydrocarbon reservoir on the surface of Titan with an estimated volume of sediments equivalent to 500.000 km^3. This is consistent with the range of organic sediment inventory given by [13] who established liquid hydrocarbon reservoir (lakes and seas) as the second organic reservoir on Titan. Further works will be carried out to investigate more deeply with RADAR, VIMS and ISS observations several "blue" and "brown" areas to better understand the physics of their setting and the type of "sand" they are made of with the integration of recent cartographic products [14-16].

References: [1] *Lorenz*, R.D. et al. (2006), Science, Vol. 312 [2] *Lorenz*, RD. and Radebaugh, J. (2009), GRL, Vol. 36, L03202 [3] *Le Corre*, L. et al. (2008), Abstract [4] *Le Gall*, A. et al. (2011), Icarus 608-624 [5] *Barnes,* J. et al. (2007), Icarus 186, 242-258 [6] *Le Corre*, L. (2009), thesis [7] *Rodriguez*, S. et al. (2006), Planetary and Space science 54, 1510,-1523 [8] *Le Mouélic*, S. et al. (2008), Journal of Geophysical research, Vol. 113 [9] *Brown*, R.H. et al. (2009), Springer [10] *Neish*, C.D., et al. (2010), Icarus 192, 77-91 [11] *Janssen*, M.A. et al. (2011), Icarus [12] *Barnes*, J. et al. (2009), Icarus 195, 400-414 [13] *Lorenz* et al. (2008), GRL Vol 35, L02206 [14] *Rubin*, D.M. and Hesp, P.A. (2009), Nature Geoscience, Vol. 2 [15] *Radebaugh*, J. (2009), Nature Geoscience, Vol. 2 [16] *Le Mouélic* et al. (2012), Planet Space Science, 73, 178-190.

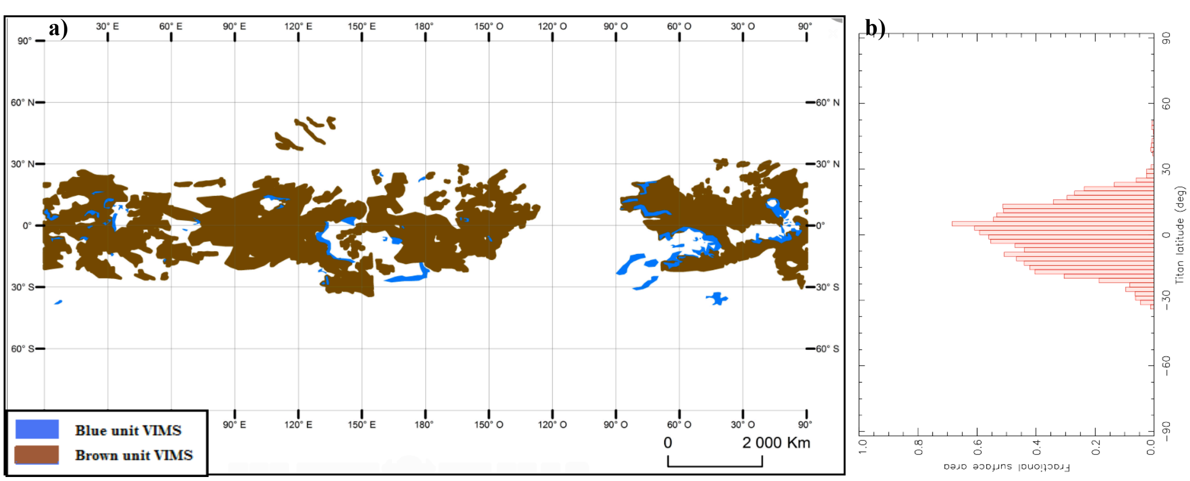

Figure 2: a) Map of the brown and blue units of VIMS extracted from the global VIMS map [9] - b) Latitudinal distribution of the brown unit.